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ABSTRACT

To determine the developmental level at which letter processing skills become automatic, an experiment was conducted using a variant of the visual search task. Subjects in grades one, two, and three and in college searched for target letters displayed on a cathode ray tube along with either visually confusable letters, acoustically confusable letters, or digits. Accuracy and reaction time of search were evaluated for evidence of the visual search "category effect," or the facilitation when the target differed from the distractor items with which it was presented. The findings revealed that (1) the visual search task was a sensitive and reliable measure of the ability of young children and adults to discriminate visually presented stimuli on the basis of visual features and categorical dimensions: (2) when category distinctions had to be maintained in memory or were not presented simultaneously in the display, subjects of all ages had difficulty using the differences in searching: and (3) subjects without a great deal of experience with stimuli such as letters and digits showed the "category effect" in the same way as older, more experienced subjects. (FL)

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The Development of Automatic Letter Processing Skills Related to Reading and Intellectual Development

by

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INTRODUCTION

Contemporary experimental reading research is quite diverse. Certainly, it can be argued that interest has swayed heavily towards the study of high level comprehension skills. Yet, we should not assume from this trend that perceptual factors are not important nor that all questions concerning them have been answered. We are among those who feel that a complete analysis of the development of reading skills must incorporate the role of perceptual processes.

With this in mind we set out to understand more clearly the developmental role of letter identification and discrimination processes. The study to be reported here is the second in a series using the visual (letter) search paradigm to measure the letter processing skills of young children and adults.

BACKGROUND

In order to set the stage for the present study, I would first like to review the initial experiment, results of which have already been reported.

We first had subjects respond with a button press as to whether the upper case letter "V" was present in a field of items presented on a cathode ray tube. The other items in the display varied in their featural and categorical similarity with the target letter. These distractor items were either visually confusable letters (W,X,Y), acoustically confusable letters (B,C,P), or digits, or Greek letters. On any single trial, either 1 or 4 items were displayed with the target present on 50% of the trials. Both accuracy and reaction time were measured. Subjects were from grades K, 1, 2, 3, and college.

We found extremely similar patterns of visual search throughout the grades sampled. When only a single item was displayed, only the college subjects could reliably search for the target faster when the distractors were less confusable with the target (as in the digit distractor set). However, with 4 items displayed, distractor set discriminability was reliable in all grades. Visually

confusable letters as distractors always led to the longest search time, digits the shortest.

Those of you familiar with the work of Egeth, Jonides, Gleitman and others will recognize this as a variant of the "category effect" in visual search, or the facilitation on reaction time when the target item is perceptually or categorically distinct from the distractor items.

We and others have suggested that this effect is an important manifestation of the degree to which subjects have automatized the features contained in the various stimuli and are thus efficiently processing these features or the letters which contain them. As this is an important skill to master before embarking on more semantic aspects of reading, recognition of its adequate development is crucial. From data concerning the category effect alone, we could not decipher any important developmental changes in children from about 5.5 to 8.5 years of age. We also collected data on several intellectual abilities tests, among them reading achievement, measures of which were significantly correlated with search speed in grades K, 1, and 2. However, the patterns associated with these correlations did not allow us to make any strong conclusions concerning the role of visual search skills in reading.

That we obtained reliable category effects for 4 items displayed but not 1 is worthy of emphasis. When differences

among distractor sets and the target letter had to be maintained in memory (1 item displayed), children had difficulty using these differences to facilitate performance. Yet, when these differences were visible in the display (4 items), strong differences in reaction time as a function of distractor set were obtained.

PRESENT STUDY

The nature of the search task is such that letter identification and discrimination processes may operate relatively independently of other processes necessary in actual reading situations. Since in the first experiment there was evidence that efficiency in letter processing skills was aided by providing competing featural information in the visual field, it seemed reasonable that memory load factors might provide a process limitation on the efficiency of letter processing skills. Therefore, in the present study, we asked whether there would be developmental differences in letter processing skills when subjects were provided with more information to be processed during the search task.

Subjects in grades 1, 2, 3, and college were asked to search for any 1 of 1, 2, or 3 target letters displayed along with either visually confusable letters, acoustically confusable letters, or digits. Each of these distractor sets contained 7 items. For each of the two letter sets and each subject, 3 letters were chosen as targets and 4 as distractors. For the digit set, each subject received 3 letters from 1 of the 2 letter sets as targets and 4 of the 7 digits as distractors. Letters only were used as targets.

The number of targets to be searched is referred to as the memory set size. In this study, the display size was 1, 2, or 4. Again, the target was present on 50% of the trials.

Figures 1 and 2 contain the important reaction time results. In Figure 1 are included the factors of grade, type of distractor set, and display size collapsed across the factor of memory set size. Just as in the first experiment, distractor sets led to differences in search time as the number of items displayed increased from 1 to 4. With a single item displayed, there were no reliable distractor set differences, even at college. For size 4, however, differences were strong and reliable in all grades. Note that in all three panels at each grade, 12 comparisons in all, the visual distractors led to the longest reaction times, and in all but 2, digits the shortest. Despite the overall gain in speed across grades, there did not appear to be important developmental changes as assessed by different patterns in the category effect.

But now consider Figure 2. These data reflect distractor set differences in memory set size for each grade collapsed across the factor of display size. It is clear that the effect of the number of targets to be searched on reaction time depends on the type of distractor set. There were stronger effects of memory set size at all grades for the more confusable items (visual: top line of each panel). The

developmental differences were more a matter of degree than of pattern. For grades 3 and college, memory set size did not affect reaction time reliably when the targets were presented along with digit distractors (bottom line of last 2 panels).

The only evidence of speed-accuracy tradeoffs in these data occurred for the college subjects who were more accurate for responses taking longer when 4 items were displayed. In general, the times were longer and accuracy higher for trials without a target. This same tradeoff was found in the previous experiment.

Reaction time measures were correlated with these psychometric tasks: Peabody Picture Vocabulary Test, Raven's Coloured Progressive Matrices, digit span forward, and the reading and mathematics subtests of the Stanford Achievement Test.

Significance patterns were weak in grades 1 and 2. One pattern of theoretical interest in grade 1 concerned the significant correlations between the digit span and reaction times with digit distractors and a single item displayed. These correlations are consistent with the hypothesis that the absence of the category effect overall for children at this small display size was due to a working memory limitation. At least in the first grade sample, children who were able to benefit from the dissimilar distractors had

higher digit span scores, and presumably, better working memories.

For grade 3, correlations were more impressive. Reaction time was correlated significantly overall with the Raven's as well as the conceptual mathematics score. Breaking these correlations down furtner, the conceptual math scores were related to reaction time uniformly across most task conditions. Of note were the significant correlations for all 3 display sizes. The Raven's scores were not as generally related to reaction time; however, the strongest correlations were for the visually confusable letters at all three display sizes with a single target to be searched.

CONCLUSIONS

Taken together with the results of the first study, several conclusions have been reached.

1. The visual search task proves to be a sensitive and reliable measure of the ability of young children and adults to discriminate visually presented stimuli on the basis on visual featural and categorical dimensions.

2. When category distinctions had to be maintained in working memory, or when these distinctions were not presented simultaneously in the visual display, then subjects of all grades tested had difficulty using the differences to facilitate search. When these distinctions were "out there" for the subject to see, then even kindergarteners possessed the ability to use perceptual or categorical distinctions among the stimuli.

3. Thus, subjects without a great deal of experience with stimuli such as letters and digits manifested the category effect in a similar fashion to much older and experienced subjects. Evidence in support of important developmental changes in this respect

must await future investigations which pursue the limitations imposed by memory load and similar factors. Finally, we believe the interesting correlations with non-verbal intellectual ability and achievement are worthy of a closer look.